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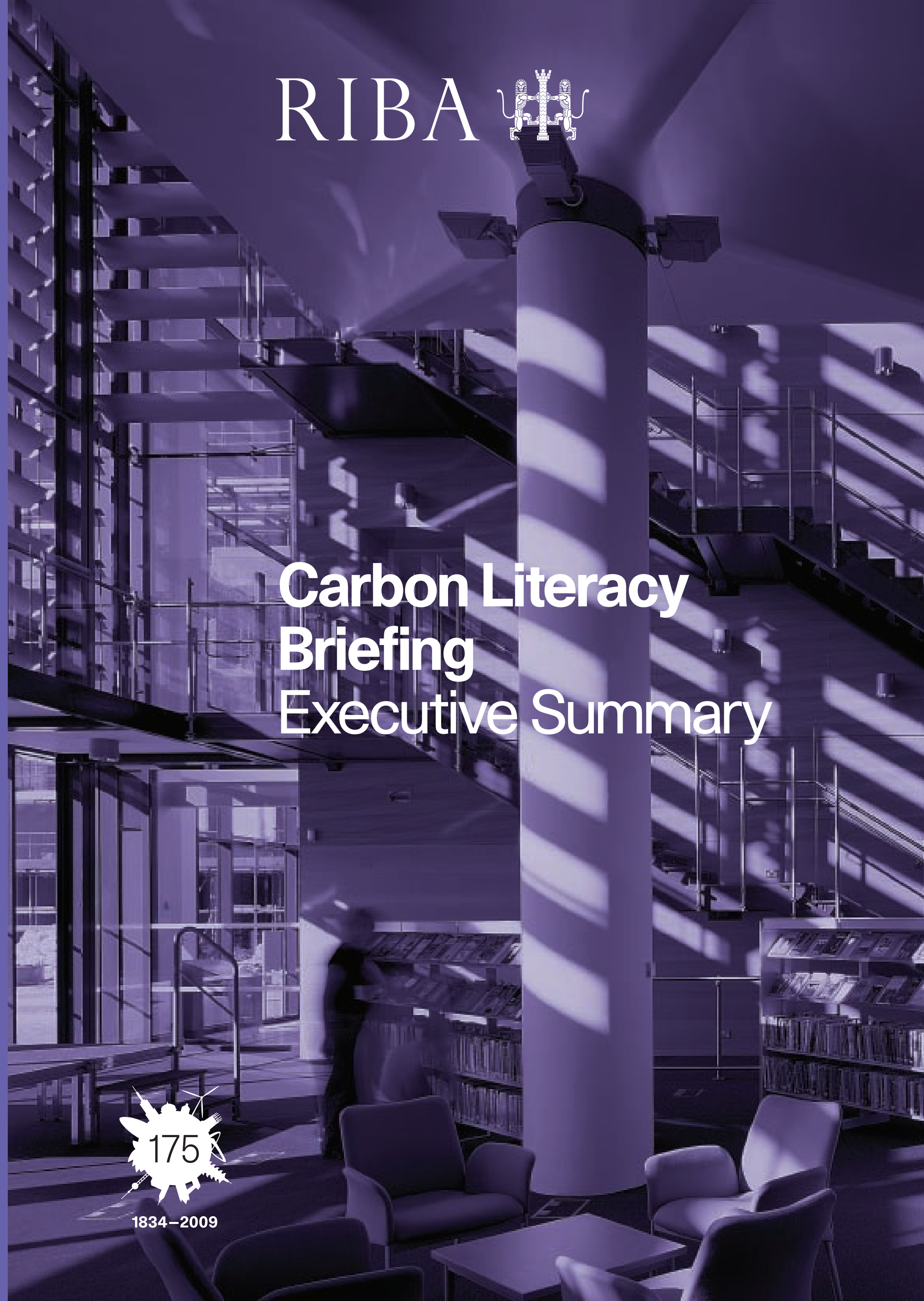

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# Carbon Literacy Briefing
## Executive Summary

175
1834–2009

## About this Document:

This document summarises the *Carbon Literacy Briefing*, developed by the RIBA as part of a suite of Climate Change Tools to encourage architects to engage with the issue of climate change and to deliver low carbon new buildings and low carbon refurbishment of existing buildings.

To download the full *Carbon Literacy Briefing*, or to explore all of the RIBA Climate Change Tools, visit www.architecture.com/climatechange

**Cover image** Jubilee Library, Brighton. The library is designed by Bennetts Associates to take advantage of the natural energy provided by the south coast setting – specifically sunshine and wind. The sun's energy is gathered through the south facing front glazed wall in winter, with built-in solar shading and automatically opening vents to reduce solar gain and glare in summer. Heat generated by people and equipment in the building is also harnessed and re-used. Energy use has been minimised, and instead of air conditioning, natural ventilation refreshes the atmosphere inside and cools the building. Wind towers on the roof use the breeze to draw excess heat from the floors below.

**Photo** Peter Cook/VIEW/ Bennetts Associates

## Introduction

In the 1960s, the famous American engineer Richard Buckminster Fuller used to ask his audiences of engineers the question: **'How much does your building weigh?'** His interest was in efficient designs that used less material but, of course, nobody could ever answer his question.

The twenty-first century equivalent of Buckminster Fuller's question is: **'How much carbon dioxide does your building emit?'**

When British architects are asked this question, they rarely know the answer. Even when architects do know how much carbon dioxide their buildings are expected to make, they rarely seem to know whether the answer is good or bad.

This guide is an attempt to address this problem, by explaining the relationship between buildings and carbon dioxide emissions, and by summarising some of the existing benchmarks for building energy use and associated emissions.

## Carbon Dioxide Emissions in Context

The *Climate Change Briefing* that forms part of the RIBA Climate Change Tools explains the mechanisms of climate change, summarises UK emissions and explains the challenge that climate change presents to our society. It can be downloaded at www.architecture.com/climatechange

Information about carbon dioxide ($CO_2$) and other greenhouse gas (GHG) emissions associated with energy use in buildings needs to be set in the broader context of climate change and why reducing emissions is important.

Climate change brought about by man-made emissions of greenhouse gases has been identified as the greatest challenge facing human society at the beginning of the twenty-first century.

In 2003, carbon dioxide emissions associated with energy use in the UK were approximately 560 million tonnes. Almost half of this came from energy use in buildings. Energy use in housing accounts for slightly more than half of the emissions associated with energy use in all buildings, amounting to 27% of the UK total.

## Energy Basics

**Energy** is measured in joules (J). This is a very small unit: 4,200 J are needed to raise the temperature of 1 kilogramme of water by 1 degree Celsius.

**Temperature** is a measure of the energy content of a body or substance. It is measured in degrees Celsius (°C) or degrees Kelvin (K), which are essentially the same. Heat always flows from a hotter body or substance to a cooler one.

**Power** is the rate of transfer of energy, or the rate of heat flow, and is measured in Watts (W). 1 Watt is 1 joule per second. 1 kilowatt (kW) is 1,000 Watts. Here are typical power ratings for some energy using and energy producing devices:

| | |
|---|---|
| Compact fluorescent lamp | 20 W |
| Electric room heater | 1 to 3 kW |
| Car engine | 100 kW |
| Community-scale wind turbine | 1 MW |
| Coal-fired power station | 1 to 5 GW |

The main units are multiples of Watts:

1 kW = 1,000 W (103)
1 MW = 1,000,000 W (106)
1 GW = 1,000,000,000 W (109)

### Heat Loss

A typical house has a heat loss of 10 kW; an energy efficient house might have a heat loss of 3 kW.

If heat losses are measured when there is a 20°C difference in temperature between inside and outside, then the specific heat loss of the energy efficient house is given by:

3000 W/20°C = 150 W/°C

The **kilowatt-hour** (kWh) is a way of expressing the amount of energy the house requires; this is the unit used on fuel bills (and 1 kWh is equal to 3.6 MJ).

### Useful Energy

This is the amount of energy that is needed to keep a building warm. The useful energy needed to keep the energy efficient house warm (at 20°C) will be:

3 kW x 24 hr = 72 kWh per day



### Delivered Energy

Building systems are rarely 100% efficient. So the amount of energy that needs to be delivered to the building will generally need to be greater than the useful energy required.

If the house is electrically heated, by a 100% efficient heater, then the delivered energy required is:

3 kW x 24 hr = 72 kWh per day of electricity

However, if the house has an 80% efficient gas boiler, then the delivered energy required is:

(3 kW x 24 hr)/0.8 = 90 kWh per day of gas

The lower the efficiency of the heating system, the more delivered energy is required to supply the useful energy requirement.

### Energy Efficiency and Carbon Dioxide Emissions Factors

For the purpose of comparing buildings, **energy efficiency** is usually expressed as the annual delivered energy requirement per unit of floorspace, measured in kWh/m$^2$/yr. It is often helpful to divide this into two components – electricity, and energy from fossil fuels.

Fossil fuels such as gas are hydrocarbons, which require oxygen when they burn, e.g.

$CH_4 + 2O_2$ -> $CO_2 + 2H_2O$

methane + oxygen -> carbon dioxide + water vapour

From the chemical equation above, it is possible to calculate the amount of carbon dioxide produced for each unit of fuel that is burnt. This is the **carbon dioxide emission factor**, which is usually expressed in kilogrammes of carbon dioxide per kilowatt-hour of fuel that is burnt (kg$CO_2$/kWh).

The carbon dioxide emission factor for mains electricity takes into account all the emissions associated with generating electricity from various fuels including coal, oil, nuclear energy and renewables.

### Emission Rates

Another comparative measure of the energy or environmental performance of buildings is the **Building Emission Rate** (BER – for non-domestic buildings) or the **Dwelling Emission Rate** (DER – for dwellings) measured in kg$CO_2$/m$^2$/yr. These are the measures used in the Building Regulations Part L and the Code for Sustainable Homes, where they are compared with a Target Emission Rate (TER) also measured in kg$CO_2$/m$^2$/yr.

## Carbon Dioxide Emissions from UK Buildings

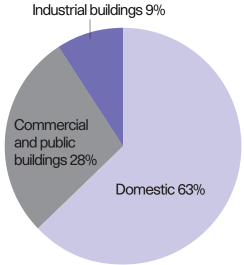



Figure 1

Figure 1 shows energy delivered to UK buildings in 2000, broken into three sectors: domestic, commercial and public buildings and industrial buildings. Buildings used nearly half of the energy delivered in the UK.

Figure 2 shows carbon dioxide emissions associated with energy use in non-domestic buildings, broken down by fuel type, in 2000. Nearly two-thirds of the emissions (61%) were associated with the use of electricity, most of which was used for lighting, mechanical ventilation, air conditioning and equipment such as computers.

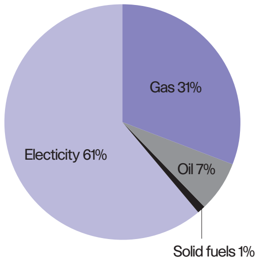



Figure 2

It is interesting to see how that energy is actually used. Figure 3 shows UK carbon dioxide emissions associated with energy use in non-domestic buildings in 2000, broken down by energy end-use. Note that heating accounted for nearly half (41%) of carbon dioxide emissions and lighting accounted for almost one quarter (23%). Cooling and ventilation contributed a relatively modest 5%, but this figure is growing.

### Existing Buildings and New Build

The UK's existing building stock consists of approximately two million non-domestic premises and approximately 25 million dwellings.

The average rate of replacement of the non-domestic building stock is approximately 1% per year, but there is much variation between sectors, and significant growth.

The average rate of replacement of the domestic building stock is approximately 0.5% per year, and there is significant new growth.

Currently the carbon dioxide emissions associated with energy use in new buildings largely cancel out the reductions obtained by improvement of existing buildings. If overall reductions in carbon dioxide emissions are to be made, either the rate of improvement or the rate of replacement of existing buildings must increase, or both.

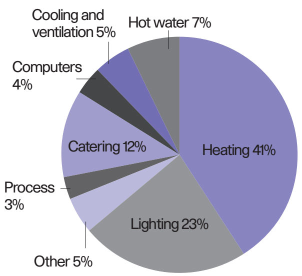



Figure 3

**Figure 1** Energy delivered to UK buildings in 2000

**Figure 2** UK carbon dioxide emissions associated with energy use in non-domestic buildings in 2000, broken down by fuel type

**Figure 3** UK carbon dioxide emissions associated with energy use in non-domestic buildings, in 2000, broken down by energy end-use

(Source: CIBSE Guide F)



## Carbon Dioxide Emissions Factors

One of the reasons that electricity accounts for such a high proportion of carbon dioxide emissions associated with energy use in buildings is that more emissions arise from using one unit of energy in the form of electricity than, for example, one unit in the form of natural gas.

The relative emissions of different types of energy are expressed in terms of a carbon dioxide emissions factor. Electricity has a high 'carbon dioxide emissions factor' compared with other fuels, more than twice that for mains gas.

Table 1 below sets out carbon dioxide emissions factors for various fuels, and their ratio with the emissions factor for mains gas.

When designing a low-carbon building, it is always better to incorporate building services that use fuels with low emissions factors – or better still, use energy from a local renewable source.

| Fuel | Carbon dioxide emissions factor (kg $CO_2$/kWh) | Emissions factor relative to mains gas |
|---|---|---|
| Mains gas | 0.194 | 1.00 |
| LPG | 0.234 | 1.20 |
| Oil | 0.265 | 1.40 |
| Solid fuel | 0.291 | 1.50 |
| Grid electricity* | 0.422 | 2.20 |
| Renewable energy | 0.000 | 0.00 |
| Wood | 0.025 | 0.13 |

**Table 1** Carbon dioxide emissions factors for some common fuels (source: SAP 2005)

*The published emissions factors for electricity are based on the Government's forward projections of the 'dash for gas' in the electricity generation industry, to 2010. These projections have not been borne out, and the current emissions factor for grid electricity is thought to be approximately 0.55 kg$CO_2$/kWh, which is 2.84 times that for mains gas

## Energy Use and Emissions Benchmarks for Buildings

To establish energy efficiency and carbon dioxide emissions standards, we need 'benchmarks', or indicators of the levels of energy use and emissions that might be considered typical, and those associated with good practice in low-carbon design and refurbishment.

### Domestic Buildings

The sections below set out carbon dioxide emissions for three typical new-build dwellings:

- A two-bedroom flat (60 m²)
- A three-bedroom semi-detached house (83 m²)
- A three-bedroom, three-storey townhouse (98 m²).

For each property type, a chart presents the estimated carbon dioxide emissions when the house is designed and specified to meet the current Building Regulations[1], and the Code for Sustainable Homes Levels 3, 4, 5 and 6.

**Figure 4** A two-bedroom flat
This example relates to a two-bedroom flat, mid-floor, mid-block with a floor area of 60m²

| Two-bedroom flat | Total carbon dioxide emissions (tonnes/yr) |
|---|---|
| Building Regulations Part L1A (2006) | 2.02 |
| Code for Sustainable Homes Level 3 | 1.73 |
| Code for Sustainable Homes Level 4 | 1.51 |
| Code for Sustainable Homes Level 5 | 0.85 |
| Code for Sustainable Homes Level 6 | 0 |

1 The house conforms to the guidance in the Approved Document to Part L1A of the Building Regulations (2006); the Dwelling Carbon Dioxide Emissions Rate (DER) is equal to the Target Carbon Dioxide Emissions Rate (TER)



**Figure 5** A three-bedroom semi-detached house
This example relates to a two-storey, three-bedroom, semi-detached house with a floor area of 83m²

| House | Total carbon dioxide emissions (tonnes/yr) |
|---|---|
| Building Regulations Part L1A (2006) | 2.96 |
| Code for Sustainable Homes Level 3 | 2.51 |
| Code for Sustainable Homes Level 4 | 2.17 |
| Code for Sustainable Homes Level 5 | 1.16 |
| Code for Sustainable Homes Level 6 | 0 |

**Figure 6** A three-bedroom townhouse
This example relates to three-storey, three-bedroom, mid-terraced townhouse with a floor area of 98m²

| House | Total carbon dioxide emissions (tonnes/yr) |
|---|---|
| Building Regulations Part L1A (2006) | 3.15 |
| Code for Sustainable Homes Level 3 | 2.73 |
| Code for Sustainable Homes Level 4 | 2.41 |
| Code for Sustainable Homes Level 5 | 1.46 |
| Code for Sustainable Homes Level 6 | 0 |

## Non-Domestic Buildings

The non-domestic building stock is far less homogenous than the domestic stock – there are far more building types.

Energy use in non-domestic buildings and the associated carbon dioxide emissions are dependent on five key factors:

- Building form
- Building fabric
- Building services
- Activity accommodated
- Management of the building.

The charts below illustrate the CIBSE benchmarks for carbon dioxide emissions for four types of existing buildings: offices, retail buildings, industrial buildings and schools[2]. In each case, 'typical' and 'good practice' benchmarks are given[3].

Where existing buildings are to be refurbished, it is appropriate to adopt energy standards equivalent to the appropriate good practice benchmark, or better.

When new buildings are being designed it is appropriate to adopt energy standards at least equivalent to 'good practice', and moving towards low- or zero-carbon standards.

2 CIBSE *Energy Efficiency in Buildings* Guide F, Chartered Institute of Building Services Engineers, London, 2004

3 In 2007, a review for CIBSE and CLG concluded that these benchmarks are inconsistent, out of date and overdue for review. A new set of stringent statutory benchmarks for use on Display Energy Certificates for public buildings is now being



## Offices

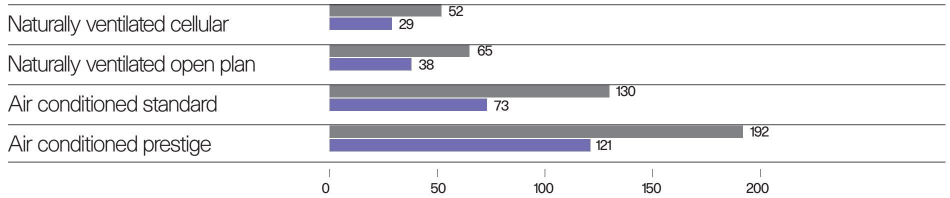
Four types of buildings are considered:

- Naturally ventilated, cellular offices
- Naturally ventilated, open-plan offices
- 'Standard' air conditioned offices
- 'Prestige' air conditioned offices (e.g. corporate headquarters).

The chart illustrates the significant emissions penalty associated with air-conditioning and increased services, where there is much more intensive use of electricity than in naturally ventilated buildings. This is why low-carbon designs should avoid air conditioning wherever possible.

**Figure 7**

Offices total carbon dioxide emissions (kg/m²/yr)

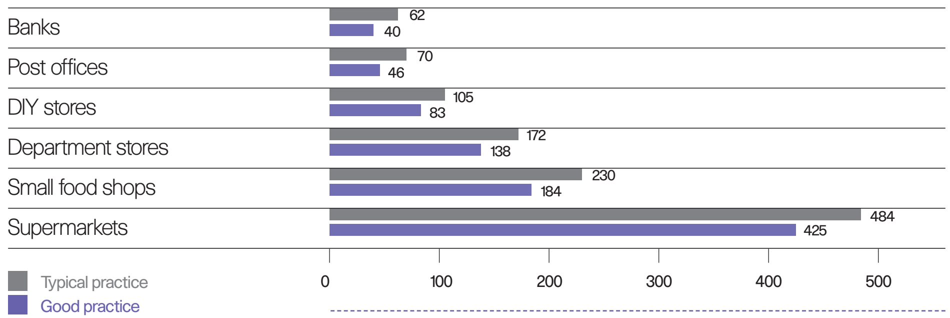



## Retail Buildings

The stock of retail buildings is very diverse. This chart shows the significant increase in carbon dioxide emissions associated with depth of plan (e.g. in department stores, supermarkets), because of the increased use of electricity for artificial lighting, mechanical ventilation and refrigeration.

**Figure 8**

Retail carbon dioxide emissions (kg/m²/yr)



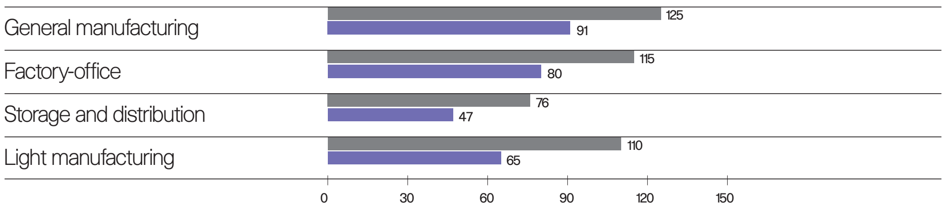

finalised. The development of voluntary benchmarks for different building sectors is also being encouraged. All of these new benchmarks are intended to have consistent technical underpinnings related to agreed allowances for buildings' needs, rather than historical statistics

### Industrial Buildings

The next chart illustrates the CIBSE carbon dioxide emissions benchmark for industrial buildings (excluding process energy). The stock of these buildings is also diverse, ranging from small unheated workshops to very large chilled warehouses. The figures for storage buildings hide the wide variation between unheated warehouses (which may only be intermittently lit) and chilled warehouses that are continuously cooled.

Figure 9

Industrial buildings carbon dioxide emissions (kg/m²/yr)



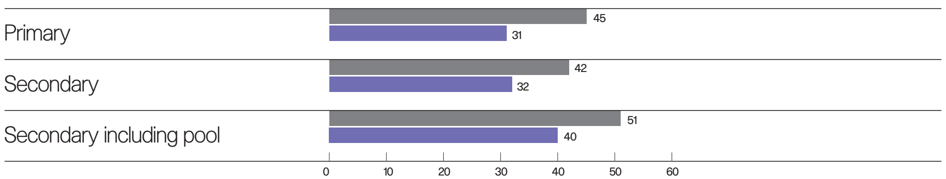

### Schools

Finally, we illustrate the CIBSE benchmark for primary and secondary schools (with and without swimming pools). These figures are for existing schools, in which energy use is notoriously variable.

The Carbon Literacy Briefing provides more detailed information about these benchmarks and how they can best be used to design, deliver and monitor low carbon buildings.

Figure 10

Schools carbon dioxide emissions (kg/m²/yr)




Typical practice
Good practice



## Energy Performance Certificates and Display Energy Certificates

**Energy Performance Certificates** (EPCs) are required when a new building is first occupied, and whenever its occupancy changes – that is, when it is sold or when there is a new tenancy.

**Display Energy Certificates** (DECs) are required for some publicly accessible buildings.

For **dwellings**, EPCs report the SAP energy ratings and Environmental Impact Ratings (EIRs, based on the SAP carbon dioxide emissions) on a banded A–G scale:

A 92–100
B 81–91
C 69–80
D 55–68
E 39–54
F 21–38
G 1–20

Band A represents excellent performance (i.e. low fuel costs and low emissions) and band G represents very poor performance (i.e. high fuel costs and high emissions).

For **non-domestic buildings**, EPCs report 'Asset Ratings' and/or 'Operational Ratings'; they are intended to send market signals about the relative performance of comparable buildings.

The Asset Rating of a new building is the ratio of the predicted carbon dioxide emissions from the building (the Building Emission Rate, BER) to a Standard Emission Rate (SER). The BER is calculated by approved software (e.g. an implementation of the Simplified Building Energy Model, SBEM).

The SER is the Reference Emission Rate (RER) multiplied by 0.765, and the RER is calculated for a reference building of the same size and shape as the actual building, specified to meet the 2002 Building Regulations, with gas-fired heating and hot water services, and in which each space is heated and cooled to fixed set-points (irrespective of whether the equivalent spaces in the actual building are heated or cooled or not). A gas-heated building that is just compliant with the 2006 Building Regulations will have an Asset Rating of 100. A better performing building (i.e. one with lower carbon dioxide emissions) will have a lower Asset Rating. EPCs present Asset Ratings on a banded A–G scale, where A represents excellent performance and G represents very poor performance:

A 0–25
B 25–50
C 51–75
D 76–100
E 101–125
F 126–150
G Over 150

In addition, an A+ rating is assigned to buildings with less than net zero carbon dioxide emissions, i.e. buildings that export more locally generated renewable energy than they take from the grid.

EPCs also report the minimum standard of performance required by the Building Regulations (the Target Emission Rate, TER) and the performance of a 'typical' building that would comply with the 1995 Building Regulations.

The Operational Rating of a building is determined some time after the building has been occupied, from measured energy use data according to an assessment and reporting methodology developed by CIBSE. It is shown on a Display Energy Certificate.

More detailed information about energy ratings and emission rates can be found in the RIBA Climate Change guide on *Low Carbon Standards and Assessment Methods*.

## Useful Links

United Nations International Panel on Climate Change (UNIPCC)
www.ipcc.ch

UK Climate Change Programme
www.defra.gov.uk/environment/climatechange/uk/ukccp/index.htm

Carbon Trust
www.carbontrust.co.uk

Energy Saving Trust
www.energysavingtrust.org.uk

RIBA Climate Change Policy
www.architecture.com/climatechange

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